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MUTUAL AID IN SPACE ORBITS

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16. Abstract

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MUTUAL AID IN SPACE ORBITS

N. Fotkin*

ABSTRACT. A detailed description of the Apollo-Soyuz docking mechanism, docking module, and radio-communication procedure is provided by Engineer N. Fotkin. The purpose of the joint docking project is explained at length: to create the ultimate backup system — another spacecraft which can be sent to replace or aid the first. The exchange of pilot-cosmonauts and astronauts, which will also take place, is part of this backup system.

What is the reliability of an ordinary workship hammer? Is it equal to unity? Not at all. It is very close to unity, but will never be equal to unity, especially in prolonged use. However, a quick glance into a tool box is sufficient to pick from two hammers the hammer which is "more reliable": in a hammer there are only two parts. /34**

This is one reliability.

Now imagine an automobile rushing along a good highway. Fifty or a hundred kilometers pass, and suddenly (you have very likely

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*Engineer.

**Numbers in the margin indicate pagination in original foreign text.

verified this recently) the engine is dead. One of the many parts which undergo stress during the motion of the automobile has gotten out of order. Such a failure is unpleasant, but it has no catastrophic consequences. Pull off to the side of the road, and the problem is removed. Automobile manufacturers try, of course, to reduce the mechanical failures to a minimum. They strengthen individual units, use stronger materials, etc. But the struggle for dependability is nevertheless restricted by definite economic limits.

This is another reliability.

The designers of equipment for space exploration, especially manned vehicles, are compelled to seek reliability in an entirely different way. If, let us say, the retro rocket fails during an attempt to descend from orbit, the consequences of this failure will be far different from the consequences of a dead car engine. But it is well known that space flight makes demands on the construction of the vehicle and its subunits which are never experienced by the machine parts in any form of surface transportation. Vibration, deep vacuum, and the cold of space are added to the "usual" overloads. And, naturally, in such conditions the possibility of failure of any of the elements of the spacecraft increases immeasurably. And if one takes into account the fact that there are not thousands, but millions of machine parts in a space rocket system, then it becomes understandable that designers give great attention to the problem of reliability of any space vehicle and its equipment.

The strongest and lightest construction materials and the most advanced manufacturing technology are used for space vehicles. Everything, from the smallest screw to the rocket body, is subjected to repeated and thorough tests under conditions similar to those of the actual launching and flight. The most important systems are duplicated and even tripled. Besides simple redundancy, in which several identical, interchangeable devices are set up on board, there is wide use of functional duplication, in which several systems solve the same problem, but their operation is based on different principles.

This is a third reliability.

However, no matter how refined the materials and technology are, no matter how high the production efficiency, how varied the testing, to achieve absolute reliability of a space rocket system (as with any other system) is impossible. Infinite duplication is impossible, because the vehicle would become so heavy that it would not take off. Therefore, even for the third and highest degree of reliability, the /35 potential possibility of failure of any system or unit remains. Consequences of such a failure depend on the role played by the defective unit or system in the general structure of the vehicle, and also on the stage of the flight in which the failure occurs.

It is well known that from the time of switching on the retro rocket for descent from orbit to the landing of the spacecraft, only several tens of minutes pass, while arrival in orbit requires even less time. On a near-Earth orbit or on a flight to other heavenly bodies, the machinery, the units and systems of the ship, and the vehicle as a whole work many hours, and sometimes even weeks. It is precisely orbital flight which forces us, as a consequence of the ever increasing duration of space flights, to look for new means and methods for guaranteeing the safety of crews in space ships and orbital stations.

What are these means? How is it possible to increase further the safety of crews in space? By the same duplication — duplication of the spacecraft itself. But not permanent duplication, as is done with onboard systems, but only when necessary, when irreparable failures suddenly arise on the ship, threatening the lives of the astronauts. During a failure, let us say, of the retro rocket, nothing will help the ship, unless another ship capable of approaching, joining up with it, and taking on board its crew rushes to its aid.

Does this mean that throughout an entire space flight a "number one" rescue ship must be ready to go on Earth? Not necessarily. In the navy, there are special rescue ships, but they are not always sent to the aid of ships which have suffered a disaster, when the disaster takes place at a great distance from the location at which the rescue ships are based. In such a case, the ship which is closest to the region of the disaster renders assistance. In this case, the national affiliations of the vessel which has suffered the disaster and of the ship rendering assistance play no role.

Common sense suggests that this proven maritime tradition must be extended to the sixth ocean — cosmic space. And for this, it is necessary that governments which are carrying out space flights unify the means for mutual search and approach of ships, unify the equipment for joining them to each other, and that they ensure the compatibility of the ships' atmospheres.

The Soviet Union and the United States of America are undertaking the first step in this direction, as only these countries are carrying out manned flights into space. In the second half of 1975, in the period from July 15 to September 21, the first experimental, joint flight of ships of the "Soyuz" and "Apollo" types is planned. The ships will dock with each other while in orbit around the Earth.

What problems will Soviet and American engineers have to solve in order to make possible the creation in orbit of a "Soyuz-Apollo" space system and the transfer of astronauts from one ship to the other?

At the present time, only ships belonging to either the U.S.S.R. or the U.S.A. are capable of docking with each other in space. The Soviet and American docking ships are functionally different from each other. One of them is passive. It has a receiving cone and carries out only oriented flight. The second is active. It has a docking pin and executes all maneuvers which are necessary for approach and docking. In addition to this, the ships' atmospheres are different on the Soviet and American vessels. The Soviet astronauts breathe the usual terrestrial nitrogen-oxygen nixture at normal pressure. On the other hand, the atmosphere of the American ships is pure oxygen at a total pressure of about 260 mm of mercury.

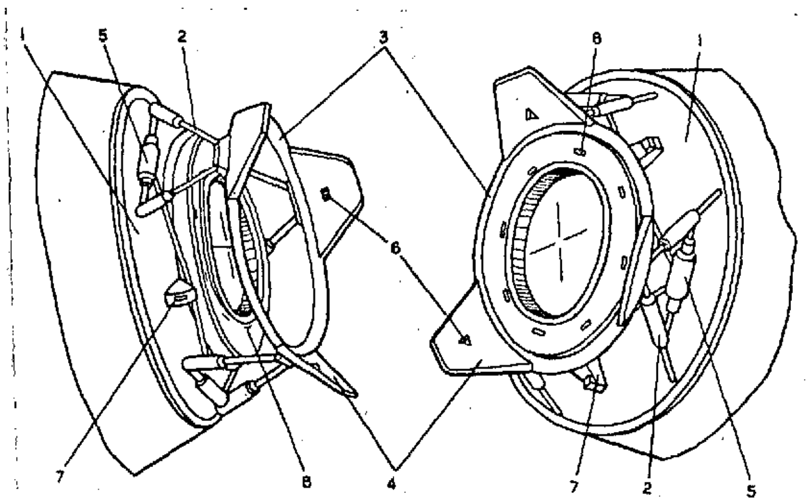
Out of the whole group of "incompatibilities" between the Soviet and American spacecraft, the principal ones — which make impossible both the creation of the Soyuz-Apollo system and the implementation by these ships of the duplicator or "rescue" functions — are the following: incompatibility of the electronic media which provide mutual detection of the ships and allow them to approach each other; incompatibility of the docking devices; incompatibility of the atmospheres within the ships, which prevents transfer of the astronauts from one ship to the other.

In order to carry out more rapidly the joint experimental flight of the Soyuz-Apollo system, the scientists and astronauts of both countries have decided for the present time to use the Apollo radio systems for search and approach of the vehicles in space. In the first flight, the Apollo will be the active ship. The radio systems will measure the parameters of relative motions of the ships, i.e., radial velocity and distance between them. The receiving part of the radio system will be set up on the Soyuz, that is, the transponder, which provides radio pickup for any relative positioning of the ships.

An optical system will be used to measure the angular position of the line of sight. With the help of this system, the crew of the Apollo will be able to observe the Soyuz from a distance of several hundred kilometers. Pulsed light beacons will be set up on the Soyuz for optical measurements in the dark (from a distance of several tens of kilometers). In the concluding stage of approach, the relative positions of the ships will be determined visually. During this stage, a special docking target set up on the Soyuz will be used in addition to television cameras, optical devices, and onboard orientation lights. Steering will be done by the ships in accordance with the recommendations of an onboard computer, into which all the measured information will be entered.

The complex and fundamentally new problem is the removal of the incompatibility in the docking devices. While up to now the pin-cone scheme was used by both countries for docking spacecraft, in the proposed flight another type of docking device will be used — an andorgynous device. With such a device, a ship is able to perform both active and passive functions. Now, specialists of the U.S.S.R. and U.S.A. have come to an agreement that, in the development of the docking devices for their own ships, the parts which make the reciprocal connections in docking will be unified. The compatibility of the docking devices will thereby be attained.

In the design scheme for a docking device of the peripheral androgynous type (see diagram), the androgyny of the assemblies is attained because of symmetric positioning of all elements which are directly connected in the docking. On the body of the docking



Active docking assembly

Passive docking assembly

Diagram of the docking device for the Soyuz-Apollo spacecraft

assembly (1), the guiding ring (3) with guiding tabs (4) is mounted through the shock absorbing rods (2). Thanks to the presence of the six shock absorbing rods, the guiding ring is a floating structure.

Before docking of the space ships, the guiding ring on the active docking assembly is moved forward with the help of the extension and contraction system (5). On the passive assembly, it remains in the drawn up position. During the mooring of the ships, the guiding rings provide the initial contact of the ships' structures and distribute the impact energy among the shock absorbers. The three guiding lobes arranged uniformly around the ring and flared outward at an angle of 45 degrees provide lateral and angular alignment of the ships for capture and securing.

Simultaneously with the impact of the ships after aligning of their axes with the help of the capture latches (6), mechanical coupling of the ships takes place. Three capture latches are arranged on the guiding ring of the ship, and three return latches (7) are arranged on the body of the other ship. Upon initial coupling, the capture latches on the active docking assembly (with extended ring) are interlocked with the three latches on the body of the passive ship. Naturally, the capture latches of the passive ship do not function at this time. /36

After the capture latches engage the return latches, the ships begin to draw together. The rods (2) are retracted. While the rods were capable of independent motion during impact, they now move synchronously. The ships draw together until impact of the joint lines of both ships. The guiding pins and sockets, which are positioned diametrically opposite, ensure a final alignment and serve as guides during the concluding stage of the coupling. The locking devices (8) of the docking ring finally unite the ships. All eight locking devices are connected with each other and with the cable drive actuator. Concentric rubber gaskets ensure the sealing of the joint.

After this operation, the two ships are a single space system, directed by either of the docked vehicles. However, it is impossible to open the hatches and transfer from the Apollo to the Soyuz or from the Soyuz to the Apollo, because their artificial atmospheres are different. If, let us say, a member of the Soviet crew went immediately from his own ship to the American ship, then we would quickly manifest the so-called decompression disorders — shortness of breath, lowered blood pressure, a sharp deterioration of his general condition. The astronaut might lose consciousness. It is possible to avert these decompression disorders by the so-called washing out of nitrogen from the organism by inhaling pure oxygen. This process is called desaturation, and requires a definite time interval. (After 15 minutes, up to approximately 1/3 of the nitrogen contained in the blood and tissues is extracted from the organism; after one hour, up to 2/3 is extracted.)

Thus, the direct transfer of an astronaut from the Soyuz to the Apollo while the different artifical atmospheres exist is ruled out. Therefore, to effect the transition, a special air lock is envisaged in which the astronauts will prepare their organisms for life in the other atmosphere. The necessity of such an air lock is dictated by a purely technical fact, namely, the difference in the environmental control systems used on the Soviet and American ships. In a Soyuz, continuous regeneration of the atmosphere takes place. In an Apollo, absorption of carbon dioxide gas takes place by means of a non-restorable absorber, while the oxygen is replenished from onboard reserves.

And what will the air lock be?

In the technical specification, it is called the docking module. The module is a hermetic cylinder with diameter of about 1.5 meters and length of 2.8 meters. On both sides of the cylinder, there are hatches with pressure difference gauges, values for equalizing pressure, and mechanisms for opening the hatches. The hatch diameter is 0.7 - 0.8 meters. On the vacant side, the module, being a component part of the Apollo, carries the androgynous device.

The internal equipment of the docking module includes means for voice and radio communication, signalling and warning, and television systems. The docking module also has its own life support system, containing subsystems for storing and supplying oxygen and air, letting off the pressure, heat control, and purification of the atmosphere from carbon dioxide. It also has a desaturation set-up with open type oxygen masks.

Before transferring between ships, the crews of the Soyuz and Apollo must carry out a series of preliminary operations. The first thing is to make a careful check of the airtightness of the compartments of their ships and the docking module. Then the Soyuz crew (if the Soviet astronaut is the first to go into the air lock) will check the airtightness of the transfer tunnel, formed after docking, and equalization will begin between the pressure in the module and the pressure in the orbital compartment of the Soyuz. When this has taken place, the hatch of the ship will be opened, and the Soviet astronaut will enter into the module. After the hatch of the Soyuz is again closed, the systems of the docking module will begin to operate. Having put on the desaturation mask, the astronaut switches on the oxygen supply. Simultaneously with this, a slow drainage of the module atmosphere is begun. By the time the desaturation is finished, the pressure in the docking module is equal to the pressure in the Apollo command section. The astronaut opens the second hatch of the module and, after switching off its systems, goes over into the American ship.

For transfer of astronauts from the Apollo to the Soyuz, the operations are carried out in reverse order. The only difference is that when the members of the Apollo crew enter the docking module, the pressurization is accomplished with air, similar to the Soyuz atmosphere, rather than with oxygen, and the astronauts do not undergo desaturation. In order to make the transition process somewhat simpler and to save time in all these operations, the pressure in the Soyuz compartments may be somewhat lowered, to about 520 mm mercury.

Besides purely technical questions, the Soviet and American engineers must solve a series of organizational-technical questions, such as ground control of the ships, communications with them, carrying out joint training, etc. In a regular meeting in October, 1973, the Soviet and American technical project directors, corresponding member of the U.S.S.R. Academy of Sciences K. D. Bushuev, and Dr. G. Lanni* certified that the operation of the joint flight is proceeding

*Translator's note. Transliterated from the Russian text.

satisfactorily in accordance with the agreed plan. Drawings of the orbital compartment of the Soyuz and the docking module of the Apollo have been exchanged. The astronauts have begun to master the ships (in fact, the Soviet crews will have a chance to pilot the Apollo, and the American crews — the Soyuz), and they are preparing to carry out the flight program, which includes, in particular, studies of the absorption of ultraviolet rays, observations on microbes, "universal furnace" experiments, and an artificial "solar eclipse" in which one ship blocks out the solar disk, while the crew of the other takes photographs of the solar corona.

The Soviet flight leader is pilot-cosmonaut of the U.S.S.R. A. S. Eliseyev; the American flight leader is P. Frank. The businesslike atmosphere in which the preparation for the experiment is taking place enables one to hope that all problems which might hinder the first joint flight of Soviet and American space ships will be successfully solved. An important step along the path toward creation of a mutual assistance system on the roadways of space will be taken.

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